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Chemical Analyses of Ground Water in the Carson Desert near Stillwater, Churchill County, Nevada, 2005

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Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
Length		
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
Volume		
liter (L)	0.2642	gallon (gal)
Mass		
milligram (mg)	3.527×10^{-5}	ounce, avoirdupois (oz)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
°F=(1.8×°C)+32
Horizontal coordinate information is in the Universal Transverse Mercator Projection, Zone 11, North American Datum of 1983 (NAD 83)
Altitude, as used in this report, refers to distance above the vertical datum.
Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).
Color is given in color units (CU); turbidity is given in nephelometric turbidity units (NTU).
Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Chemical Analyses of Groundwater in the Carson Desert near Stillwater, Churchill County, Nevada

Introduction

This report presents the chemical analyses of ground-water samples collected in 2005 from domestic wells located in the Stillwater area of the Carson Desert (fig. 1). These data were evaluated for evidence of mixing with nearby geothermal waters (Fosbury, 2007). That study used several methods to identify mixing zones of ground and geothermal waters using trace elements, chemical equilibria, water temperature, geothermometer estimates, and statistical techniques.

In some regions, geothermal sources influence the chemical quality of ground water used for drinking water supplies. Typical geothermal contaminants include arsenic, mercury, antimony, selenium, thallium, boron, lithium, and fluoride (Webster and Nordstrom, 2003). The Environmental Protection Agency has established primary drinking water standards for these, with the exception of boron and lithium. Concentrations of some trace metals in geothermal water may exceed drinking water standards by several orders of magnitude.

Geothermal influences on water quality are likely to be localized, depending on directions of ground water flow, the relative volumes of geothermal sources and ground water originating from other sources, and depth below the surface from which water is withdrawn. It is important to understand the areal extent of shallow mixing of geothermal water because it may have adverse chemical and aesthetic effects on domestic drinking water. It would be useful to understand the areal extent of these effects.

Study area

The Stillwater geothermal area is located in the Carson Desert hydrographic area in north-central Nevada. The community of Stillwater is located about 20 km east of the city of Fallon, near the center of the Stillwater geothermal area (Garside and Schilling, 1979). Carson Desert is a hydrologically closed basin at the terminus of the Carson River basin (Figure 1).

Four aquifers have been defined in Carson Desert, including a consolidated basalt aquifer and three unconsolidated, basin-fill, sedimentary aquifers. The three basin-fill, sedimentary aquifers are designated as shallow (0-15 m or 0-50 ft), intermediate (15-152 m or 50-500 ft), and deep (>152 m or >500 ft). The primary basis for these designations is water chemistry, particularly water hardness (Glancy, 1986).

The principal source of recharge to the shallow basin-fill aquifers in the Stillwater area is upwelling water from the intermediate aquifer, and infiltration of surface water from irrigation, which is supplied from the Carson River and Truckee Canal. Three hundred and seventy miles of lined and unlined canals supply water to irrigated fields in the Carson Desert, primarily for alfalfa production (Lico and Seiler, 1994). Previous studies show that residents of the Carson Desert are exposed to high levels of trace elements in the ground water, including arsenic (As) and tungsten (W), which are potentially related to geothermal activity in the area (Lico and Seiler, 1994; Lico et al., 1987; Seiler et al., 2005; Welch and Lico, 1998). These studies have also suggested that high

concentrations of total dissolved solids (TDS) in Stillwater well-waters are due to evapoconcentration of recharge water.

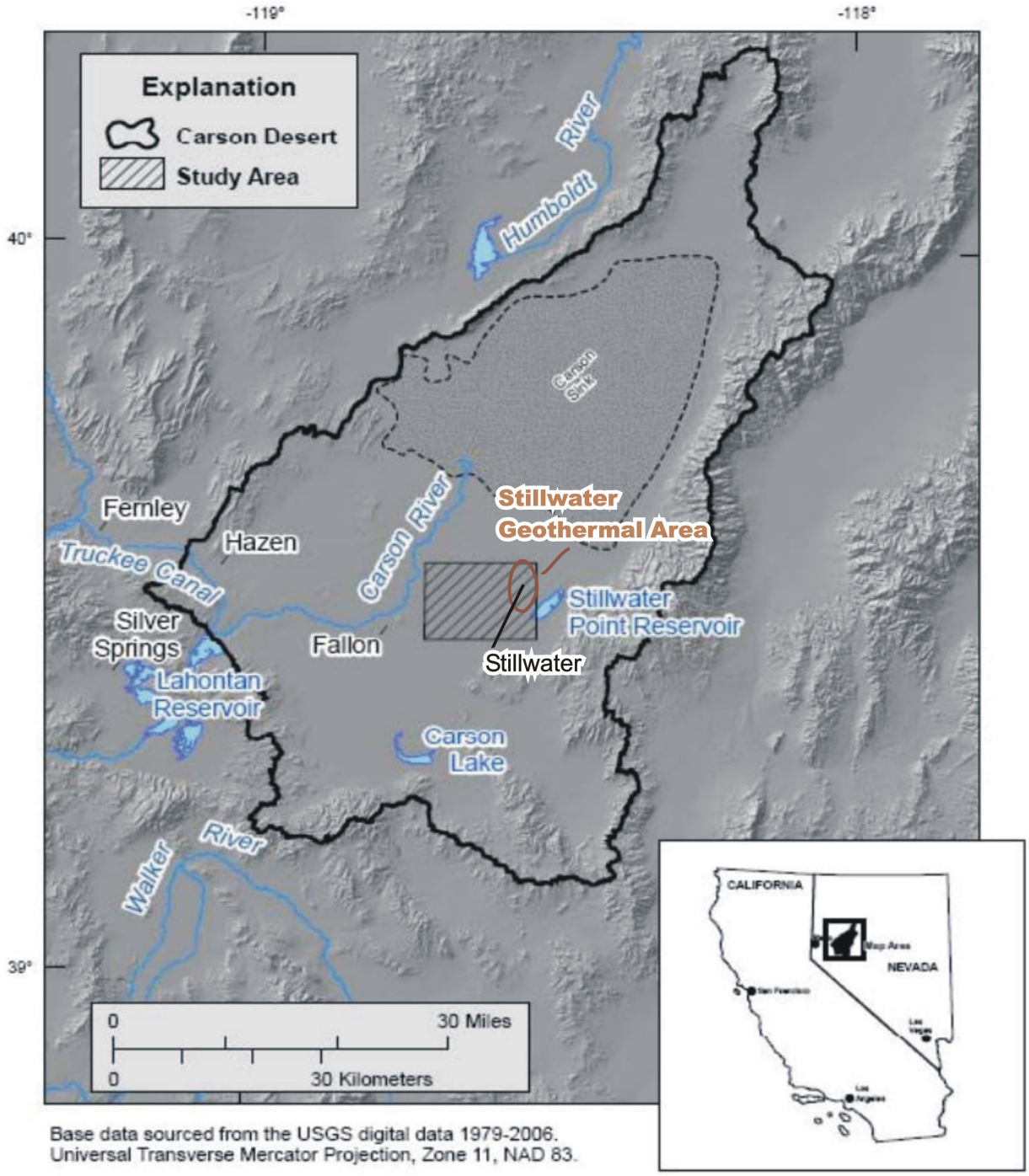

Figure 1. Location of the study area in Churchill County, NV USA.

Sampling procedures

Wells in and around Stillwater were sampled once each in June and July of 2005. Table 1 presents location and depth of wells included in the study. Well coordinates were obtained using a geographic positioning system (Garmin GPSmap 76S). Estimated well depths were obtained from interviews with well owners.

For low temperature domestic wells (water temperature <45°C), samples were taken from the spigot closest to the pump and upstream of any water treatment or storage equipment. A YSI Multiprobe with flow-through cell was used to measure water chemical and physical properties (temperature, pH, specific conductance, and dissolved oxygen) in preparation for sample collection. Each well was purged until readings for temperature, pH, and dissolved oxygen remained constant for 5 minutes. The samples were not filtered. Samples for $\delta^{18}O$ and $\delta^{2}H$ analysis were collected in 5-mL glass bottles and sealed with parafilm. Acidified and untreated samples were collected in plastic bottles provided by the Nevada State Health Laboratory. Table 2 lists methods and associated reporting limits.

The YSI Multiprobe and flow-through cell could not be used with hot waters (>45°C). Hot domestic wells were sampled from the spigot after purging 56—75 liters and temperature remained constant for 5 minutes. Temperatures were measured with a hand-held thermometer. Two samples from a geothermal power plant (P1 and P2) were taken from valves closest to wellheads. Temperatures were measured by facility personnel. The open-air method of sampling at the power plant resulted in a great deal of steam loss from these samples, which must be considered when interpreting results.

Chemical data for ground water samples

Laboratory methods

All sample analyses, excluding isotopes, were performed by the Nevada State Health Laboratory (NSHL), on the campus of the University of Nevada, Reno, in Reno, Nevada. The methods used for each analyte are listed in Table 2. Isotope samples ($\delta^{18}O$ and $\delta^{2}H$) were analyzed at the University of Nevada, Reno Stable Isotope Laboratory. Water-$\delta^{2}H$ analyses were performed using the method of Morrison et al. (2001). Water-$\delta^{18}O$ analyses were performed using the CO_2 - H_2O equilibration method of Epstein and Mayeda (1953). One field blank and 4 field duplicates were collected and analyzed for the full suite of analytes, in order to assess for quality assurance.

Table 1: Locations and depths of wells included in the study

Well Designation	UTM Zone 11 Easting	UTM Zone 11 Northing	Longitude	Latitude	Total Well Depth m (ft)
1	367195	4375744	-118.545052	39.521083	9 (30)
2	366536	4375907	-118.552749	39.522449	10 (33)
3	364752	4377825	-118.573887	39.539446	15 (50)
4	367102	4375991	-118.546183	39.523294	12 (40)
5	366821	4375846	-118.549422	39.521944	15 (50)
6	367087	4375912	-118.546342	39.522580	11 (35)
7	367253	4375857	-118.544400	39.522110	11 (37)
8	365029	4375524	-118.570198	39.518764	8 (25)
9	362985	4374752	-118.593809	39.511487	9 (28)
10	365762	4375064	-118.561581	39.514736	8 (25)
11	364688	4374498	-118.573955	39.509469	310 (1017)
12	364652	4375068	-118.574489	39.514598	9 (31)
13	366013	4376813	-118.559014	39.530529	6 (20)
14	365981	4376791	-118.559382	39.530325	152 (500)
15	363809	4374817	-118.584241	39.512204	6 (20)
16	363791	4374776	-118.584442	39.511832	10 (34)
17	364316	4378813	-118.579161	39.548276	49 (160)
19	357390	4372648	-118.658417	39.491627	7 (22)
21	355647	4370785	-118.678275	39.474556	11 (36)
22	358468	4372374	-118.645827	39.489337	6 (19)
23	361363	4371528	-118.611999	39.482188	8 (25)
25	355215	4370813	-118.683301	39.474736	44 (145)
26	356533	4372041	-118.668248	39.486017	6 (20)
27	356379	4372460	-118.670129	39.489765	6 (20)
28	356562	4372510	-118.668012	39.490246	6 (20)
29	356380	4372546	-118.670135	39.490540	6 (20)
30	356440	4371273	-118.669861	39.479074	8 (25)
32	355492	4372242	-118.680392	39.487653	6 (20)
33	355476	4370512	-118.680203	39.472069	5 (15)
34	358262	4372356	-118.648218	39.489141	4 (14)
35	356267	4370770	-118.671066	39.474525	4 (13)
36	357291	4373970	-118.659851	39.503517	8 (25)
37	357963	4374026	-118.652050	39.504133	8 (25)
38	366678	4377863	-118.551490	39.540090	125 (410)
39	366725	4378334	-118.551037	39.544339	70 (230)
40	366787	4378341	-118.550317	39.544412	6 (20)
41	366682	4377256	-118.551321	39.534623	70 (230)
42	363922	4372847	-118.582524	39.494478	6 (20)
P1	366122	4378638	-118.558114	39.546984	814 (2672)
P2	366477	4378327	-118.553921	39.544238	381 (1250)

Table 2: Analytical methods used by Nevada State Health Laboratory

Chemical Constituent	Preservative	Analytical Method	Laboratory Reporting Limit
Alkalinity as $CaC0_3$	none	SM[1] 2320 B	20 mg/l
Antimony	15 % HNO_3 (5 ml)	EPA[2] 200.8	1 µg/l
Arsenic	15 % HNO_3 (5 ml)	EPA 200.8	3 µg/l
Barium	15 % HNO_3 (5 ml)	EPA 200.7	0.02 mg/l
Bicarbonate	none	SM 2320 B	25 mg/l
Boron	15 % HNO_3 (5 ml)	EPA 200.7	0.5 mg/l
Calcium	15 % HNO_3 (5 ml)	EPA 200.7	5 mg/l
Carbonate	none	SM 2320 B	12 mg/l
Cesium	15 % HNO_3 (5 ml)	EPA 200.8	1 µg/l
Chloride	none	EPA 300.0	250 mg/l
Color	none	SM 2120 B	3 CU
Copper	15 % HNO_3 (5 ml)	EPA 200.7	0.02 mg/l
Electrical Conductivity	none	SM 2510	10 µS/cm
Fluoride	none	SM 4500 F C	0.2 mg/l
Hardness	15 % HNO_3 (5 ml)	EPA 200.7	33 mg/l
Hydroxide	none	SM 2320 B	7 mg/l
Iron	15 % HNO_3 (5 ml)	EPA 200.7	0.05 mg/l
Lithium	15 % HNO_3 (5 ml)	SM 3500 Li B	0.05 mg/l
Magnesium	15 % HNO_3 (5 ml)	EPA 200.7	5 mg/l
Manganese	15 % HNO_3 (5 ml)	EPA 200.7	0.02 mg/l
Mercury	15 % HNO_3 (5 ml)	EPA 245.2	0.2 µg/l
Nitrate + Nitrite as N	10% H_2SO_4 (1 ml)	EPA 300.0	0.5 mg/l
pH	none	EPA 150.0	n/a
Temperature	none	EPA 150.0	n/a
Potassium	15 % HNO_3 (5 ml)	EPA 200.7	5 mg/l
Selenium	15 % HNO_3 (5 ml)	EPA 200.8	1 µg/l
Silica (as SiO_2)	15 % HNO_3 (5 ml)	EPA 200.7	1 mg/l
Sodium	15 % HNO_3 (5 ml)	EPA 200.7	25 mg/l
Sulfate	none	EPA 300.0	25 mg/l
Thallium	15 % HNO_3 (5 ml)	EPA 200.8	0.5 µg/l
Total Dissolved Solids	none	SM 2540 C	25 mg/l
Tungsten	15 % HNO_3 (5 ml)	EPA 200.8	1 µg/l
Turbidity	none	EPA 180.1	0.4 NTU
Zinc	15 % HNO_3 (5 ml)	EPA 200.7	0.05 mg/l

[1](American Public Health Association., 1998)
[2](U.S. Environmental Protection Agency)

Chemical data

Chemical data for groundwater samples are presented in Table 3. Samples numbers 1-39 were collected from domestic water wells, while samples P1 and P2 were collected from the Stillwater geothermal power plant.

Quality assurance

Quality assurance data are presented in Table 4. Analysis of the field blank was below reporting levels, for all analytes. Precision of the duplicate samples was expressed as the percent relative standard deviation (%RSD), also called the coefficient of variation (eqn. 1; Skoog et al., 2000). Duplicate samples generally showed a %RSD of 0-5%.

$$\%RSD = \frac{s}{\bar{x}} \times 100\% \quad (1)$$

Where

s = standard deviation, and

$\bar{x}$ = the mean of duplicate samples.

Table 3. Chemical analyses of ground water samples. Well locations and depth are in Table 1. "<RL" = less than the reporting limit.

Sample	1	2	3	4	5	6	7	8	9	10	11
Field Water Temperature (^{o}C)	40.1	19.8	19.7	19.0	22.0	33.2	25.9	13.8	18.0	19.12	39.7
pH	7.78	8.21	8.19	8.22	8.23	8.02	8.19	7.98	8.12	8.27	8.06
pH Temperature (^{o}C)	17.6	18.3	17.9	18.2	19	18.4	18.1	18	18.3	18.9	18.1
Electrical Conductivity (μS/cm)	8300	2000	9300	1300	5100	3000	2900	820	6900	1900	6900
Total Dissolved Solids (mg/L)	5405	1360	5328	881	3028	1832	1720	529	4236	1145	4015
Hardness (mg/L)	867	281	165	149	122	514	233	203	663	162	155
Turbidity (NTU)	0.2	0.2	2.7	0.2	0.2	2.6	0.2	0.2	1.3	0.2	0.2
Color (CU)	5	5	50	5	5	7	5	7	7	5	5
Alkalinity as $CaCO_3$ (mg/L)	274	297	792	319	246	352	306	189	330	304	85
Antimony (μg/L)	1	3	<RL	2	<RL	2	3	<RL	4	2	<RL
Arsenic (μg/L)	94	200	43	190	7	77	160	17	230	310	<RL
Arsenic III (μg/L)	60	9	12	<RL	<RL	<RL	<RL	<RL	110	<RL	<RL
Barium (mg/L)	0.05	0.04	0.36	0.08	0.07	0.28	0.13	0.06	0.03	0.04	0.11
Bicarbonate (mg/L)	334	362	966	389	300	429	373	230	402	371	103
Boron (mg/L)	16	2.2	18	1.7	12	6.5	4.3	0.6	5.2	1.5	15
Calcium (mg/L)	240	53	25	40	49	140	57	55	84	32	62
Carbonate (mg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Cesium (μg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	80
Chloride (mg/L)	2300	260	3000	170	1400	710	700	72	1800	320	2200
Copper (mg/L)	<RL	<RL	0.1	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Fluoride (mg/L)	1.3	1.1	0.83	1.4	4.5	0.6	1.2	0.4	2.3	3.1	4.1
Hydroxide (mg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Iron (mg/L)	<RL	<RL	1.2	<RL	0.44	1.3	0.08	0.09	0.36	<RL	0.13
Lithium (μg/L)	1.9	0.52	1	0.31	1.7	0.68	0.61	0.1	0.65	0.43	2.1
Magnesium (mg/L)	65	36	25	12	<RL	40	22	16	110	20	<RL
Manganese (mg/L)	1.3	0.09	0.13	0.07	0.05	0.66	0.05	0.16	0.14	<RL	0.06
Mercury (μg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Nitrate + Nitrite as N (mg/L)	<RL	<RL	1.3	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Potassium (mg/L)	43	20	52	7	22	19	16	7	54	16	21
Selenium (μg/L)	8	2	3	1	4	2	3	<RL	6	2	6
Silica (mg/L)	111	60	56	64	94	79	68	34	60	60	75
Sodium (mg/L)	1500	340	2000	240	1100	450	540	99	1200	360	1400
Sulfate (mg/L)	800	400	<RL	98	210	170	150	130	680	180	160
Thallium (μg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Tungsten (μg/L)	12	5	32	9	58	5	5	2	4	3	44
Zinc (mg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
$\delta^{18}O$ (VSMOW ‰)	-11.53	-10.61	-11.69	-10.79	-11.91	-11.03	-10.84	-8.68	-10.49	-10.15	-12.51
$\delta^{2}H$ (VSMOW ‰)	-102	-89.5	-104.8	-90.8	-103.7	-95.7	-93.8	-81	-91.1	-86.2	-109.7

Table 3. Chemical analyses of well water samples (continued).

Sample	12	13	14	15	16	17	19	21	22	23	25
Field Temp (^{o}C)	17.0	19.4	65.0	16.0	16.1	21.612	13.8	22.5	18.2	18.2	20.1
pH (SU)	8.29	8.02	7.8	8.08	7.93	8.01	8.16	7.84	8.27	7.95	8.51
pH Temperature (^{o}C)	18.5	17.6	18.3	16.9	17.6	18.9	18.7	17.8	17.7	16.8	20.7
Electrical Conductivity (μS/cm)	630	5000	7000	820	980	7000	1100	1700	1300	3400	3600
Total Dissolved Solids (mg/L)	392	3332	4108	572	660	3988	736	1204	856	2088	2170
Hardness (mg/L)	180	526	207	231	254	174	232	573	195	651	16.5
Turbidity (NTU)	0.2	0.2	0.6	0.2	0.2	0.2	0.2	0.2	0.2	0.45	0.2
Color (CU)	5	7	5	20	7	5	5	20	7	7	80
Alkalinity as $CaCO_3$ (mg/L)	176	496	100	219	198	153	255	361	221	526	749
Antimony (μg/L)	2	3	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Arsenic (μg/L)	40	370	<RL	26	19	9	15	17	24	170	<RL
Arsenic III (μg/L)	<RL	230	<RL	<RL	<RL	11	<RL	<RL	<RL	<RL	<RL
Barium (mg/L)	0.08	0.03	0.16	0.14	0.12	0.15	0.11	0.15	0.09	0.13	0.04
Bicarbonate (mg/L)	213	605	122	267	241	186	311	440	269	642	842
Boron (mg/L)	0.5	8.6	16	0.7	0.7	14	0.9	1.1	1.5	1.6	11
Calcium (mg/L)	49	100	83	66	72	58	70	170	55	160	<RL
Carbonate (mg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	36
Cesium (μg/L)	<RL	<RL	160	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Chloride (mg/L)	52	990	2200	45	86	2300	100	190	180	840	750
Copper (mg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Fluoride (mg/L)	0.7	2.2	4.5	0.6	0.3	2.4	0.4	0.4	0.3	0.8	2.1
Hydroxide (mg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Iron (mg/L)	<RL	<RL	0.08	<RL	<RL	0.15	<RL	<RL	0.05	0.05	<RL
Lithium (μg/L)	0.1	1	1.8	0.08	0.08	1.6	0.07	0.14	0.08	0.21	0.07
Magnesium (mg/L)	14	67	<RL	16	18	7	14	36	14	61	<RL
Manganese (mg/L)	0.1	0.09	0.07	<RL	0.05	0.26	0.37	0.16	0.21	<RL	<RL
Mercury (μg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Nitrate + Nitrite as N (mg/L)	0.6	6	<RL	8.9	9.9	<RL	1.3	16	0.9	0.6	<RL
Potassium (mg/L)	8	31	31	10	8	22	8	<RL	6	12	13
Selenium (μg/L)	<RL	3	3	<RL	2	6	1	1	5	<RL	5
Silica (mg/L)	47	68	94	39	26	56	39	39	43	53	51
Sodium (mg/L)	67	930	1400	92	120	1400	160	140	210	490	820
Sulfate (mg/L)	69	820	170	110	140	120	160	240	170	160	65
Thallium (μg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Tungsten (μg/L)	3	4	53	1	2	34	1	1	6	<RL	100
Zinc (mg/L)	<RL	<RL	0.17	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
$\delta^{18}O$ (VSMOW ‰)	-10.2	-11.33	-12.43	-9.58	-9.41	-12.54	-10.93	-10.63	-10.64	-10.43	-14.95
$\delta^{2}H$ (VSMOW ‰)	-87.6	-95.8	-109.2	-84.8	-84.2	-110.6	-92.3	-89	-88.8	-89.5	-116.8

Table 3. Chemical analyses of well water samples (continued).

Sample	26	27	28	29	30	32	33	34	35	36	37
Field Temp (^{o}C)	18.72	19.52	16.19	16.7	22.48	16.23	17.51	16.51	17.25	19.83	14.76
pH (SU)	8.18	8.03	8.04	8.15	8.03	8.2	8.22	8.14	8.13	7.96	8.1
pH Temperature (^{o}C)	20.6	21.2	20.7	20.8	21.1	21.1	20.9	20.7	20.7	20.7	20.7
Electrical Conductivity (μS/cm)	930	1300	1800	1900	1100	980	980	1600	1300	780	1700
Total Dissolved Solids (mg/L)	601	860	1174	1286	742	614	634	1034	824	480	1132
Hardness (mg/L)	311	281	390	293	340	374	307	469	299	192	402
Turbidity (NTU)	0.2	0.2	0.2	0.55	0.6	0.2	0.2	0.2	1	0.2	0.2
Color (CU)	5	20	15	20	15	1.5	7	5	7	5	15
Alkalinity as $CaCO_3$ (mg/L)	278	330	378	422	266	177	287	264	308	251	490
Antimony (μg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Arsenic (μg/L)	16	19	9	9	15	12	71	26	54	16	16
Arsenic III (μg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Barium (mg/L)	0.19	0.14	0.1	0.03	0.16	0.09	0.04	0.21	0.1	0.1	0.11
Bicarbonate (mg/L)	339	403	461	514	324	216	350	322	376	306	598
Boron (mg/L)	0.6	1.1	1.4	1.8	0.9	0.4	0.6	0.9	1.1	0.7	1.5
Calcium (mg/L)	95	78	110	81	100	110	80	140	90	54	110
Carbonate (mg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Cesium (μg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Chloride (mg/L)	56	88	180	140	76	110	43	250	98	42	83
Copper (mg/L)	<RL	<RL	<RL	<RL	0.03	<RL	<RL	<RL	<RL	<RL	0.02
Fluoride (mg/L)	0.2	0.2	<RL	0.2	0.4	0.2	0.4	<RL	0.6	0.4	0.4
Hydroxide (mg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Iron (mg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	0.23	<RL	<RL
Lithium (μg/L)	0.09	0.1	0.11	0.12	0.1	0.07	0.14	0.1	0.11	0.1	0.13
Magnesium (mg/L)	18	21	28	22	22	24	26	29	18	14	31
Manganese (mg/L)	0.02	0.41	1.6	0.88	0.02	<RL	0.03	2.2	0.7	0.19	2.5
Mercury (μg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Nitrate + Nitrite as N (mg/L)	2.4	2.1	5	2.4	5.2	1.8	9.5	<RL	0.7	0.8	2.2
Potassium (mg/L)	7	12	10	12	6	7	16	8	6	<RL	6
Selenium (μg/L)	<RL	2	<RL	2	<RL	4	<RL	<RL	1	<RL	<RL
Silica (mg/L)	32	41	30	43	34	30	36	47	34	43	41
Sodium (mg/L)	85	170	250	330	120	66	95	160	160	100	230
Sulfate (mg/L)	120	220	270	390	190	140	130	210	210	90	310
Thallium (μg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Tungsten (μg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	2	2	<RL	2
Zinc (mg/L)	0.05	<RL	<RL	<RL	0.05	<RL	<RL	<RL	<RL	0.05	<RL
$\delta^{18}O$ (VSMOW ‰)	-10.59	-10.93	-10.7	-10.69	-10.77	-11.48	-10.88	-10.85	-10.96	-10.25	-10.89
$\delta^{2}H$ (VSMOW ‰)	-89.2	-90.3	-89.7	-89.9	-90.4	-93.7	-90.5	-90.5	-91	-87	-91.3

Table 3. Chemical analyses of well water samples (continued).

Sample	38	39	40	41	42	P1	P2
Field Temp (^{o}C)	85	82	21.98	79	14.22	139.44	142.33
pH (SU)	7.91	7.85	8.19	7.9	8.14	8.25	7.51
pH Temperature (^{o}C)	20.8	20.8	20.8	20.8	20.9	18.8	19.4
Electrical Conductivity (μS/cm)	7100	7200	2300	7100	1800	8000	7500
Total Dissolved Solids (mg/L)	4040	4092	1542	4120	1160	4815	4424
Hardness (mg/L)	205	182	472	182	318	177	177
Turbidity (NTU)	3.8	0.2	0.2	0.2	0.45	0.7	0.9
Color (CU)	12	7	7	5	5	5	5
Alkalinity as $CaCO_3$ (mg/L)	112	131	375	103	520	58	70
Antimony (μg/L)	2	2	2	<RL	<RL	<RL	2
Arsenic (μg/L)	4	7	160	<RL	52	18	26
Arsenic III (μg/L)	<RL	9	<RL	<RL	<RL	34	20
Barium (mg/L)	0.2	0.24	0.09	0.18	0.05	0.08	0.14
Bicarbonate (mg/L)	136	159	457	126	634	71	85
Boron (mg/L)	15	15	2	16	1.8	23	18
Calcium (mg/L)	82	73	110	73	78	71	71
Carbonate (mg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Cesium (μg/L)	170	130	<RL	170	<RL	53	130
Chloride (mg/L)	2200	2200	370	2200	110	2600	2400
Copper (mg/L)	0.02	<RL	<RL	<RL	<RL	<RL	<RL
Fluoride (mg/L)	4.1	4.4	0.8	4.3	1.2	3.2	4.8
Hydroxide (mg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Iron (mg/L)	0.66	0.11	<RL	0.1	0.15	0.55	0.59
Lithium (μg/L)	2	2	0.38	2	0.24	3.8	2.2
Magnesium (mg/L)	<RL	<RL	48	<RL	30	<RL	<RL
Manganese (mg/L)	0.12	0.25	0.04	0.04	0.62	0.02	0.03
Mercury (μg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Nitrate + Nitrite as N (mg/L)	<RL	<RL	3.9	<RL	<RL	<RL	<RL
Potassium (mg/L)	28	45	21	30	9	68	100
Selenium (μg/L)	4	4	4	6	<RL	5	11
Silica (mg/L)	111	120	62	103	45	158	145
Sodium (mg/L)	1300	1400	340	1500	290	1600	1500
Sulfate (mg/L)	160	150	280	170	270	180	180
Thallium (μg/L)	<RL	<RL	<RL	<RL	<RL	4	0.9
Tungsten (μg/L)	56	56	3	55	<RL	47	48
Zinc (mg/L)	0.06	<RL	<RL	<RL	<RL	<RL	<RL
$\delta^{18}O$ (VSMOW ‰)	-12.5	-12.56	-10.45	-12.62	-10.41	-11.06	-11.95
$\delta^{2}H$ (VSMOW ‰)	-110.7	-110.9	-89.6	-110.7	-88.7	-104.4	-108.9

Table 4. Quality assurance data. "dup" = duplicate, "std dev" = standard deviation between (btwn) the sample and its duplicate.

Sample #	20	18	%relative	24	%relative	31	%relative	43	%relative
description	**field blank**	**dup of #17**	**std dev** btwn 17&18	**dup of #23**	**std dev** btwn 23&24	**dup of #30**	**std dev** btwn 30&31	**dup of #42**	**std dev** btwn 42&43
Alkalinity as CaCO3 (mg/L)	2	156	1	527	0	269	1	523	0
Antimony (μg/L)	<RL	<RL		<RL		<RL		<RL	<RL
Arsenic (μg/L)	<RL	9	0	170	0	15	0	52	0
Arsenic III (μg/L)	<RL	10	7	<RL	<RL	<RL	<RL	<RL	<RL
Barium (mg/L)	<RL	0.16	5	0.13	0	0.15	5	0.05	0
Bicarbonate (mg/L)	<RL	190	2	643	0	328	1	638	0
Boron (mg/L)	<RL	14	0	1.5	5	0.9	0	1.9	4
Calcium (mg/L)	<RL	59	1	160	0	98	1	80	2
Carbonate (mg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Cesium (μg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Chloride (mg/L)	<RL	2200	3	800	3	78	2	110	0
Copper (mg/L)	<RL	<RL	<RL	<RL	<RL	0.03	0	<RL	<RL
Fluoride (mg/L)	<RL	2.4	0	0.8	0	0.4	0	1.2	0
Hydroxide (mg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Iron (mg/L)	<RL	0.09	35	0.05	0	0.11	<RL	0.15	0
Lithium (μg/L)	<RL	1.5	5	0.21	0	0.1	0	0.23	3
Magnesium (mg/L)	<RL	7	0	62	1	22	0	31	2
Manganese (mg/L)	<RL	0.26	0	<RL	<RL	0.02	0	0.63	1
Mercury (μg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Nitrate+Nitrite as N (mg/L)	<RL	<RL	<RL	0.5	13	5.1	1	<RL	<RL
Potassium (mg/L)	<RL	24	6	12	0	<RL	<RL	9	0
Selenium (μg/L)	<RL	4	28	<RL	<RL	<RL	<RL	<RL	<RL
Silica (mg/L)	<RL	58	2	53	0	34	0	47	3
Sodium (mg/L)	<RL	1400	0	490	0	110	6	300	2
Sulfate (mg/L)	<RL	110	6	160	0	190	0	260	3
Thallium (μg/L)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Tungsten (μg/L)	<RL	34	0	<RL	<RL	<RL	<RL	<RL	<RL
Zinc (mg/L)	<RL	<RL	<RL	<RL	<RL	0.05	0	<RL	<RL
$\delta^{18}O$ (VSMOW ‰)		-12.5	0	-10.46	0	-10.76	0	-10.38	0
$\delta^{2}H$ (VSMOW ‰)		-110.8	0	-89.2	0	-89.8	0	-88	-1

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References Cited

American Public Health Association, American Water Works Association, Water Pollution Control Federation, & Water Environment Federation, 1998, Standard Methods for the Examination of Water and Wastewater: including bottom sediments and sludges (20th ed.): Washington, D.C., American Public Health Association.

Epstein, S., and Mayeda, T., 1953, Variation of O^{18} content of waters from natural sources: Geochimica et Cosmochimica Acta, v. 4, p. 213-224.

Fosbury, D, 2007, Identifying the influences of geothermal sources on shallow aquifer water quality: Reno, NV, University of Nevada, Reno, M.S. thesis, 66 p.

Garside, L.J., and Schilling, J.H., 1979, Thermal waters of Nevada: Nevada Bureau of Mines and Geology Bulletin 91, 168 p.

Glancy, P.A., 1986, Geohydrology of the basalt and unconsolidated sedimentary aquifers in the Fallon area, Churchill County, Nevada: U.S. Geological Survey Water Supply Paper 2263, 62 p.

Lico, M.S., Welch, A.H., and Hughes, J.L., 1987, Geochemistry of ground water in the shallow alluvial aquifer, Carson Desert, western Nevada, *in*: Averett, R.C., and McKnight, D.M., (eds.), Chemical Quality of Water and the Hydrologic Cycle: Chelsea, MI, Lewis Publishers, p. 89-109.

Lico, M.S., and Seiler, R.L., 1994, Ground-water quality and geochemistry, Carson Desert, western Nevada, U.S. Geological Survey Open File Report 94-0031, 91 p.

Morrison, J., Brockwell, T., Merren, T., Fourel, F., and Phillips, A.M., 2001, On-line high-precision stable hydrogen isotopic analyses on nanoliter water samples: Analytical Chemistry, v. 73, p. 3570-3575.

Seiler, R.L., Stollenwerk, K.G., and Garbarino, J.R., 2005, Factors controlling tungsten concentrations in ground water, Carson Desert, Nevada:. Applied Geochemistry, v. 20, p. 423-441.

Skoog D.A., West D.M., Holler, F.A., and Crouch, S. R., 2000, Analytical chemistry: An introduction (7th ed.): Fort Worth, TX, Saunders College Pub., 773 p.

U.S. Environmental Protection Agency, website accessed May, 2008, Clean Water Act Analytical Test Methods: http://www.epa.gov/waterscience/methods/

Welch, A.H., and Lico, M.S., 1998, Factors controlling As and U in shallow ground water, southern Carson Desert, Nevada: Applied Geochemistry, v. 13, p. 521-539.
Webster, J.G., and Nordstrom, D.K., 2003, Geothermal arsenic; the source, transport and fate of arsenic in geothermal systems, *in*: Stollenwerk, K.G., (ed.), Arsenic in Ground Water: Boston, MA, Kluwer Academic Publishers, p. 101-125.